August 26, 2010

Mr. Mark Whittaker
Energy*Solutions*
140 Stoneridge Drive
Columbia, SC 29210

SUBJECT: CERTIFICATE OF COMPLIANCE NO. 9321, REVISION NO. 0, FOR THE MODEL NO. 3-60B PACKAGE

Dear Mr. Whittaker:

As requested by your application dated June 30, 2009, as supplemented on February 26, June 18, and July 27, 2010, enclosed is Certificate of Compliance No. 9321, Revision No. 0, for the Model No. 3-60B package. The staff's Safety Evaluation Report is also enclosed.

Energy*Solutions* has been registered as a user of the package under the general license provisions of 10 CFR 71.17. This approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471.

If you have any questions regarding this certificate, please contact me or Pierre Saverot of my staff at (301) 492-3408.

Sincerely,

**/RA/**
Eric Benner, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9321
TAC No. L24354

Enclosures: 1. Certificate of Compliance No. 9321, Rev. No. 0
2. Safety Evaluation Report

cc w/encls: R. Boyle, Department of Transportation
J. Shuler, Department of Energy

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SAFETY EVALUATION REPORT
Docket No. 71-9321
Model No. 3-60B Package
Certificate of Compliance No. 9321
Revision No. 0

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**SAFETY EVALUATION REPORT**
**Model No. 3-60B Package**
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**Revision No. 0**

## SUMMARY

By application dated June 30, 2009, as supplemented February 26, June 18, and July 27, 2010, Energy*Solutions* requested approval of the Model No.3-60B package as a Type B (U)-96 package. Revision No. 3 of the package application, dated July 27, 2010, supersedes in its entirety the application dated June 30, 2009.

The package is designed for the transport of (i) by-product, source or special nuclear material in the form of inorganic solids or dewatered resins and (ii) activated or contaminated non-fuel bearing reactor or accelerator components or segments of components. The maximum total weight of the contents, including secondary containers and cavity spacers, is 9,500 lbs.

The packaging body consists of a 1 ¼-inch thick external stainless steel shell and a ¾-inch thick internal stainless steel shell. The annular space between the inner and outer shells is filled with a 6-inch thick layer of lead. A 12-gauge stainless steel thermal shield is welded to the exterior of the external shell to provide protection during hypothetical accident fire condition events. A bolting ring provides sealing and bolting surfaces for the lid at the top end of the packaging. The 10 ½-inch thick lid is sealed with a pair of elastomer O-rings and sixteen bolts. The bottom end of the packaging consists of an external circular 3-inch thick stainless steel plate, a 5-inch thick lead shield, and a ¾-inch inner containment baseplate. The containment boundary is defined as the inner shell of the packaging body, the inner baseplate, the lid, the primary lid bolts, the inner O-rings and the vent and drain port plugs. The toroidal-shaped impact limiters are constructed of fully welded stainless steel shells filled with a crushable foamed-in-place closed-cell rigid polyurethane foam, with specifications described in the application. The outer dimensions of the package with impact limiters are 165 inches in length by 82 inches in diameter. The maximum weight of the package, including contents, is 80,000 pounds.

The package was evaluated against the regulatory standards in 10 CFR Part 71, including the general standards for all packages, and performance standards for Type B(U) packages under normal conditions of transport and hypothetical accident conditions. The analyses performed by the applicant demonstrate that the package provides adequate structural, thermal, containment, and shielding protection under normal and accident conditions.

NRC staff reviewed the application using the guidance in NUREG 1609, "Standard Review Plan for Transportation Packages for Radioactive Material." Based on the statements and representations in the application, and the conditions listed below, the staff concludes that the package meets the requirements of 10 CFR Part 71.

### References

Energy*Solutions* “Safety Analysis Report for the Model No. 3-60B Type B Shipping Cask,” Revision No. 3, dated July 27, 2010.

## 1.0 GENERAL INFORMATION

The Model No. 3-60B package is a Type B(U)-96 package designed for the transport of by-products, sources, special nuclear materials, activated reactor or accelerator components or segments of such components. The loading of the contents can be performed either in a pool ("wet environment") or in a dry loading area. Unloading of the contents is normally performed in a dry environment, typically at a licensed disposal site.

### 1.1 Packaging

The packaging body consists of a 1 ¼-inch thick external stainless steel (ASTM A240, Type 304L) shell and a ¾-inch thick internal stainless steel shell. The annular space between the inner and outer shells is filled with a 6-inch thick layer of lead. A 12-gauge stainless steel thermal shield is welded to the exterior of the external shell to provide protection during hypothetical accident (HAC) fire condition events.

The top end of the packaging body consists of a bolting ring (ASTM A-182 Gr. F45) that provides sealing and bolting surfaces for the lid. The lid, constructed of several stainless steel disks with a total thickness of 10 ½-inch, is sealed with a double elastomer O-ring and sixteen equally spaced 1 ½-inch diameter bolts (ASTM A-354 Gr. BD). A test port hole is provided through the seal ring plate between the O-rings for periodic and pre-shipment leak testing to verify proper seal closure.

The bottom end of the packaging body has an outer 3-inch thick stainless steel shell, a 5-inch thick lead shield layer (ASTM B-29 commercial grade) and a ¾-inch inner containment layer.

The external shell of the impact limiters, fabricated from stainless steel, has an 82-inch diameter (a 52-inch inside diameter) and extends approximately 15 inches beyond the outside wall of the packaging. The volume inside the shell is filled with a crushable, closed-cell polyurethane foam.

The packaging is equipped with two sets of trunnions (upper and lower), as lifting and tie down devices, which are considered as structural parts of the packaging. There are three packaging closure devices: the closure lid, the drain port located at the bottom of the package, and the vent port located in the closure lid. Both the drain and vent ports are sealed shut during transport.

Approximate dimensions and weights are as follows:

| | |
|---|---|
| Height | 125-5/8 inches |
| Outer diameter | 51-1/2 inches |
| Cavity height with lid installed | 109-3/8 inches |
| Cavity diameter | 35 inches |
| Overall package height, with impact limiters | 165 inches |
| Overall package diameter, with impact limiters | 82 inches |
| Gross weight (packaging and contents) | 80,000 lbs |
| Maximum total weight of contents, including secondary containers and cavity spacers | 9,500 lbs |

## 1.2 Contents

The package is designed to transport by-products, sources, special nuclear materials, and activated reactor or accelerator components or segments of components.

### 1.2.1 Type and Form of Materials

Allowable contents consist of:

- Dewatered inorganic solids, including powdered or dispersible solids,
- Inorganic solidified materials,
- Dewatered inorganic resins, and
- Activated and/or contaminated non-fuel-bearing reactor or accelerator components or segments of components.

### 1.2.2 Maximum Quantity of Materials

The Model No. 3-60B package is authorized for transport of Type B quantities of radioactive materials, as indicated above, up to a maximum of 1110 TBq (30,000 Ci) of Co-60 or equivalent, with a decay heat limited to 500 Watts. Equivalency to other radionuclides is not determined by the $A_2$ value but by the total energy and its spectrum. Pure alpha or beta emitters are limited by the decay heat.

The specific activity of radioactive powdered or dispersible solids shall not exceed 330 Ci/gram of Co-60 or equivalent.

Fissile material can be transported provided that the mass limits specified in 10 CFR 71.15 are not exceeded; any content that contain more than 0.74 TBq (20 Ci) of plutonium must be in solid form.

### 1.2.3 Loading Restrictions

The contents shall be packaged in secondary containers. Shoring must be placed between the secondary container and the package cavity to prevent movement during accident conditions of transport.

Contents shall be placed such that the center of gravity of the package is at approximately the same location as the geometric center of the package – "approximately the same location" being defined as having a ±10% difference in distance of the inside cavity dimensions from the geometric center of the package in any direction.

## 1.3 Drawings

The packaging is constructed and assembled in accordance with Energy*Solutions* Drawing No. C-002-165024-001, sheets 1-5, Rev. 0

## 1.4 Evaluation Findings

A general description of the Model No. 3-60B package is presented in Section No. 1.0 of the package application, with special attention to design and operating characteristics and principal safety considerations. Drawings for structures, systems and components important to safety are included in Section No. 1.3 of the application.

The package application identifies the Energy*Solutions* Quality Assurance Program for the Model No. 3-60B package and the applicable codes and standards for the design, fabrication, assembly, testing, operation, and maintenance of the package.

The staff concludes that the information presented in this section of the application provides an adequate basis for the evaluation of the Model No. 3-60B package against 10 CFR Part 71 requirements for each technical discipline.

## 2.0 STRUCTURAL EVALUATION

The objective of the structural review is to verify that the structural performance meets the requirements of 10 CFR Part 71, including performance under normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

### 2.1. Description of Structural Design

The packaging body consists of a 1 ¼-inch thick external stainless steel shell and a ¾-inch thick internal stainless steel shell. The annular space between the inner and outer shells is filled with a 6-inch thick layer of lead, which is gamma-scanned to ensure lead integrity. A bolting ring provides sealing, through a pair of solid elastomer O-rings, and bolting surfaces for the 10.5-inch thick lid. The base of the packaging consists of a 3-inch thick circular external steel plate, 5-inches of lead, and a 0.75-inch inner steel plate.

All the metal components of the packaging body, except the bolting ring and the inner shell, are constructed of ASTM A-240 Type 304L stainless steel. The bolting ring is constructed of ASTM A-182 Gr. F45 and the inner shell is constructed of ASTM A-240 Gr. 45. The bolting used for connecting the lid to the cask body is specified to be ASTM A-354 Gr. BD material.

The impact limiters are constructed from fully welded stainless steel (ASTM A240, Type 300) shells filled with a crushable closed-cell polyurethane foam with a density of 25 $lbs/ft^3$. The polyurethane, foamed-in-place and allowed to expand until the void is completely filled, bonds to the shell and creates a unitized construction for the impact limiters. The polyurethane foam technical specifications are included in the document ES-M-172, Rev. 3, included in the application. Eight attachment points connect each of the impact limiters to the packaging body. The package has two sets of trunnions used for lifting, handling and tie-down.

### 2.2 Design Criteria

Section No. 2.1 of the application summarizes the structural design criteria for the package, including codes and standards.

The containment boundary is evaluated based on the American Society of Mechanical Engineers (ASME) code requirements for Level A and D service, and is consistent with Regulatory Guide 7.6, "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels." However, ASME B&PV Code, Section III, Appendix F, Article F-1335, is used for allowed bolting material. The allowable stress limits used for NCT and HAC conditions are appropriately referenced from R.G. 7.6.

Table 2-2 of the application lists the allowable stresses for various stress components under NCT and HAC loading conditions. Staff performed an independent check of the calculated allowable levels and confirmed that the values are accurate. The staff confirmed that the bolt allowable limits are in accordance with NUREG/CR-6007. ASME Nuclear Code Case N-284 is also appropriately used for the buckling acceptance criteria.

During the review of this package application, the staff determined that the use of impact limiter mechanical properties were inconsistent with the guidance from the polyurethane foam manufacturer, titled "Design Guide for Use of LAST-A-FOAM FR-3700." The applicant provided additional supporting information in Energy*Solutions* report ST-618, Rev. 0, which demonstrated the applicability of their approach and was acceptable to the staff to satisfy regulatory requirements. Loads and load combinations were evaluated using Regulatory Guide 7.8, "Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Materials."

The applicant provided tables that tabulated the calculated stress intensity levels at the worst locations of selected components. Table No. 2-1 of the application provides the summary of load combinations for NCT and HAC loadings. Table No. 2-3 of the application presents how the regulatory and ASME codes are incorporated into the analyses performed to demonstrate compliance of the package with regulatory requirements.

The package structural integrity is predicated on analytical modeling. More information can be "extracted" from a structural simulation than from numerous tests but it is imperative that modeling results be reliable and consistent with both the data and the overall structural behavior obtained from either a full scale or model testing. The applicant used drop test data from a Vitrified High Level Waste (VHLW) package to validate the results of its analytical modeling technique using a finite element code, ANSYS/LS-DYNA. The VHLW package's geometry, materials, and polyurethane foam impact limiters are similar to those of the Model No. 3-60B package. Full scale VHLW prototype packages were tested for HAC drop conditions at both Sandia National Laboratories and the German Federal Institute for Materials Research and Testing (BAM) test site. The applicant demonstrated (in Energy*Solutions* report ST-551, Rev. 2) that the analytically calculated deceleration values could be conservatively predicted against the test data. In order to avoid any significant hour-glass energy in the model, hour-glass control was employed for the impact limiter foam, and the model was constructed by eight node solid elements with fully integrated formulation. Subsequently, the applicant evaluated the package by using a two-step approach, which included numerical dynamic modeling to determine peak decelerations for five package orientations, and then incorporated in quasi-static numerical stress and deformation evaluations. Results are provided in Energy*Solutions* report ST-504, Rev. 2.

The applicant provided a sensitivity analysis of the package in Energy*Solutions* report ST-596, Rev. 0. The results of the analysis show that the grid density refinement beyond the base grid density, established in the drop analysis of the package, does not have an appreciable effect on the computed results for the explicit finite element model (FEM). Therefore, the staff agreed that the FEM grid density used in Energy*Solutions* report ST-557, Rev. 1, is appropriate.

The applicant also provided a grid convergence study for the quasi-static FEM (ANSYS) and demonstrated that the modeling techniques employed in constructing the ANSYS FEMs, used for the analyses of the Model No. 3-60B package, adequately represent the package structure in the most vulnerable area, i.e., the bolting ring - inner/outer shell region. The applicant further demonstrated that the element selection and the selection of the element sizes in this bolting ring- inner/outer shell region predict that the results are within small tolerances of the corresponding theoretical values.

Based on the validation analysis presented, the staff agreed with the developed analytical modeling technique that conservative analytical solutions can be predicted for HAC cases for the package. The structural design criteria for the Model No. 3-60B package have adequate structural integrity to meet NCT and HAC requirements of 10 CFR Part 71.

## 2.3 Weights and Centers of Gravity

The maximum gross weight of the package is 80,000 pounds including the maximum gross weight of the payload of 9,500 pounds. The center of gravity of the package is considered to be located at approximately the same location as the geometric center of the package.

## 2.4 Codes and Standards

As specified in the packaging drawings, the following codes and standards are applicable to the package design and fabrication.

Structural materials which are important to safety are specified using ASTM standards, i.e., ASTM A-240 Type 304 L for the external packaging shell, thermal shield, seal ring, drain line, bushing thread; ASTM A-182 Gr. F45 for the bolt ring, ASTM A-354 Gr. BD alloy steel for the lid bolts, and ASTM B-29 for the lead shielding. The ASTM B-29 grade is intended for applications requiring corrosion protection and formability.

Welding procedures and personnel are qualified in accordance with the ASME Code, Section IX. The fabrication, examination and inspection of the containment boundary components are per ASME Code Section III, Subsection ND.

## 2.5 Material Properties and Specifications

Materials of construction are designated on the licensing drawings. All the metal components of the packaging body, except the bolting ring and the inner shell, are specified to be ASTM A-240 Type 304L stainless steel. The bolting ring and the inner shell, specified to be ASTM A-182 Gr. F45 and ASTM A-240 Gr. 45 respectively, are approved for construction. The material properties for these materials are obtained from the ASME Code.

Type 304 stainless steel has no ductile to brittle transition at the normal operating temperatures above -40°F. The melting point of the Type 304 stainless steel (2700°F) is well above any temperature the package is expected to experience. The long duration operating temperature range of the elastomer O-ring material was confirmed to be -40°F to 300°F. The requirements of 10 CFR 71.71(b) are met.

The material properties of the packaging components used in the analysis are given in Table No. 2-3 of the application. The temperature dependent yield stress, ultimate tensile strength, allowable membrane stress, Young's modulus and mean coefficients of thermal expansion for stainless steel, carbon steel and lead were spot checked against the values in ASME B&PV Code Section II, Part D, and NUREG/CR0481, "An Assessment of Stress-Strain Data Suitable for Finite Element Elastic-Plastic Analysis of Shipping Containers," and found to be within tolerance. The requirements of 10 CFR 71.55(d)(1) and (2) are met. Likewise, the temperature dependent specific heat and thermal conductivity of stainless steel, carbon steel and lead, as shown in Table No. 3-6 of the application, were checked and found to be adequate.

The potential for galvanic, chemical, and other reactions has been evaluated. The applicant specifies that the materials for fabrication of the package (stainless steel, lead, elastomer O-ring, and foam) along with the contents of the package will not cause significant chemical, galvanic, or other reaction in an air, nitrogen, or water atmosphere. In addition, no significant degradation of their mechanical properties can be expected under the radiation field produced by the contained radioactivity. The payload of the Model No. 3-60B package is heavily shielded; therefore the radiation exposure of the overpack materials (including the polyurethane foam) is negligible. The silicone rubber containment seal, which is also located outside of the gamma shielding, likewise receives a negligible exposure. For these reasons, there will be no deleterious radiation effects on the packaging. The staff concludes that, during normal operation, the package's internals will not be subject to continuous or frequent exposure to moisture or that any water intrusion is not likely to occur in great quantities. The number of and galvanic potential between the different metals used in the fabrication is low. Therefore, the conditions required to create the possibility for galvanic corrosion are small. Further, visual inspections to be performed of the payload cavity at various timed intervals provide reasonable assurance against any significant corrosion occurring unnoticed. The requirements of 10 CFR 71.43(d) are met.

The bolting used for connecting the lid to the cask body, specified to be ASTM A-354 Gr. BD material, is approved for use in the ASME Section III, Subsection ND vessels.

The material properties for the poured-in-place lead shielding, specified to be ASTM B-29 lead, are obtained from NUREG/CR-0481.

The lid, vent, and drain port seals, specified to be elastomer O-rings, have a temperature range of -40°F to 300°F and a hardness in the range of 50-70 Durometer. Seals with such specifications have been successfully used in similar packages.

The impact limiters are filled with a closed-cell rigid polyurethane foam. The foam is procured per the applicant' specification ES-M-172, included in an Appendix to the application, which uses a 25 $lb/ft^3$ nominal density foam's stress-strain properties perpendicular-to-rise direction as a required property. The type of foam specified is Type FR-3700 or FR-6700 from General Plastics Manufacturing Company. The applicant is using both perpendicular-to-rise and parallel-to-rise direction properties, as appropriate, for the analyses of the impact limiters.

The applicant specifies that all the metal components of the package are fabricated from austenitic stainless steel. Brittle fracture has not been addressed explicitly in the application. The staff agrees that austenitic stainless steels are not susceptible to brittle failure at temperatures encountered in transport and that no tests are needed to demonstrate resistance to brittle failure per Regulatory Guide 7.11. Bolts are also not considered as fracture-critical components because multiple load paths exist and bolting systems are generally redundant per Section 5 of NUREG/CR-1815, "Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inch Thick," August 1981.

## 2.6 Fabrication and Examination

Section Nos. 2.3.1 and 2.3.2 of the application indicate that the containment components of the Model No. 3-60B packaging are based on ASME B&PV Code, Section III, Subsection ND-5000, while the non-containment components are be based on ASME B&PV Code, Section III, Subsection NF-5000. Examination of the components is based on the codes referenced above. Thus, containment boundary welds are required to be inspected by radiographic examination (RT), and meet the acceptance requirements of ASME Code, Section III, Division I, Subsection ND, Article ND-5320. Non-containment boundary welds are required to be inspected by ultrasonic examination (UT) and meet the acceptance requirements of ASME Code, Section III, Division I, Subsection ND, Article ND-5330 or NF, Article NF-5330. Welds on lifting and tie-down trunnions are required to be inspected by liquid penetrant examination (PT) and meet the acceptance requirements of ASME Code, Section III, Division I, Subsection ND, Article NF-5350. Inspections shall be performed before and after the 150% load test.

The applicant uses its NRC approved 10 CFR Part 71 Quality Assurance Program, which implements a graded approach to quality based on a component's or material's importance to safety consistent with the guidance provided in NUREG/CR-6407 to assure all materials used to fabricate and maintain the package are procured with appropriate documentation which meet the appropriate tests and acceptance criteria for packaging materials.

## 2.7 Lifting and Tie-Down Standards for All Packages

The Model No. 3-60B package has two pair of trunnions for lifting, handling, and tie-down operations. These trunnions are a structural part of the package. The applicant developed a half-symmetry ANSYS model representing the trunnion assembly. The boundary conditions were placed to have no additional stress effect on the trunnion assembly. The attachment welds in the trunnions were also modeled to determine the weld stress. The methodology and results are documented in Energy*Solutions* report ST-503, Rev. 1.

### 2.7.1 Lifting Devices

The package is designed to be lifted with the help of a lifting yoke, using the two upper trunnions. A dynamic factor of 1.3 was used for the trunnions under lifting conditions. It was demonstrated by the analyses to have acceptable margins of safety for design and can be operated safely.

The applicant states that any other part of the package that could be used to lift the package (e.g., impact-limiter lifting lugs) will be rendered inoperable during the transportation of the package. Based on the review of the application, the staff determines that the regulatory requirement is met.

The analysis of the lifting loading was determined that the stress intensity levels in the trunnions are much closer to the allowable limit, than those of the cask shell at vicinity of the trunnions. Therefore, failure of the lifting devices will not impair the ability of the package. Based on the review of the calculations, the staff agrees with this conclusion and determines that this regulatory requirement is met.

The staff concluded that all conditions of 10 CFR 71.45(a) are met.

### 2.7.2 Tie-Down Devices

The trunnions are used to tie-down the 3-60B package during transportation.

The finite element analysis, used to determine the stress intensity levels at the critical locations under the three-directional simultaneously combined loading conditions, demonstrated acceptable margins of safety for the design. Based on the review of the calculations, the staff determines that the regulatory requirement of 10 CFR 71.45(b)(1) is met.

The applicant stated that any other part of the package that could be used for the tie-down (e.g., impact-limiter lifting lugs) will be rendered inoperable during the transportation of the package. Based on the review of the application, the staff determines that the regulatory requirement of 10 CFR 71.45(b)(2) is met.

The analysis of the tie-down loading has shown that the stress intensity levels in the trunnions are much closer to the allowable limit, than those of the cask shell at vicinity of the trunnions. Therefore, failure of the tie-downs will not impair the ability of the package. Based on the review of the calculations, the staff agrees with this conclusion and determines that the regulatory requirement of 10 CFR 71.45(b)(3) is met.

The staff concluded that all conditions of 10 CFR 71.45(b) are met.

## 2.8 General Standard for All Packages

### 2.8.1 Minimum Package Size

The overall packaging dimensions of 51 ½ inches diameter and 125 5/8 inches in length are greater than the minimum overall dimension of 4 inches. Therefore, the package meets the requirements of 10 CFR 71.43(a).

### 2.8.2 Tamper-Indicating Features

The package is equipped with a tamper resistant seal installed between the packaging body and each of the two impact limiters. The package, which cannot be opened by an unauthorized person without damaging the seal, is in compliance with the tamper-indication requirement of 10 CFR 71.43(b).

### 2.8.3 Positive Closure

Sixteen 1 ½ inch-6UNC bolts fasten the lid to the cask body. The drain and vent ports are also closed with threaded attachments. These closure components are encompassed within the two impact limiters. Therefore, the containment system cannot be opened unintentionally and the requirements of 10 CFR 71.43(c) are satisfied.

### 2.8.4 Material Corrosion

The package is primarily fabricated from stainless steel, lead, and polyurethane foam. These materials will not cause chemical, galvanic, or other reaction in air or water environments. The package meets the requirements of 10 CFR 71.43(d).

### 2.8.5 Failure of Package Valves

The package does not have any safety valves that could induce a breach of containment and the requirements of 10 CFR 71.43(e) are met.

## 2.9 Normal Conditions of Transport

The applicant demonstrates compliance of the package with NCT conditions by analytical methods as indicated in Section No. 2.2 of this SER. The finite element model is described in Energy*Solutions* document ST-501, Rev. 2, and the ANSYS finite element analysis code is used.

Since the lid of the package is attached to the body using sixteen 1-1/2 inch hex head bolts, the cask geometry has a cyclic symmetry every 11.25° of the circumference. Therefore, an 11.25° model of the package is made using three-dimensional 8-node structural solid elements (ANSYS SOLID185) to represent the major components of the package, package body, lid, and bolts. The inner and outer shells and the base-plates are represented in the finite element model by SOLSH190 elements. The fire shield is not included in the model since it does not provide any structural strength to the package.

The model includes (i) finer mesh around the lid, seal-plate, and bolts to determine specific results due to localized conditions, (ii) stainless steel as the package body and lid, carbon steel as the hex-head lid bolts, and lead for the shielding, and uses temperature dependent material properties of the components of the package. The interface between the lead and the steel is modeled by contact (CONTA174) and target (TARGE170) elements.

The model is conservatively restrained in the vertical direction at the skirt instead of the entire bearing surface of the upper impact limiter. Also, since the model represents an 11.25° circumferential symmetry, the nodes on the cut-planes are restrained from displacement normal to these planes.

NCT loading conditions of deadweight, internal pressure, and temperature are considered in the analyses. Because of the segmentation of arc length in the finite element model, the mass of the model is lower than the actual mass of the package. Therefore, to account for this missing mass an acceleration amplification factor of 1.107g is calculated and used.

A 180° (half symmetry) finite element model was developed (based off of the 11.25° model) for the drop conditions. The center of gravity of the package was considered to be located at the same location as the geometric center of the package. An explicit dynamic finite element code, ANSYS/LS-DYNA, is used to predict the deceleration levels for the drop cases. The deceleration levels are then taken to perform quasi-static analyses using ANSYS. The rigid body motion is prevented in the model by restraining it at the locations where such restraints had insignificant effect on the overall behavior of the model. The analyses are performed for sufficiently large durations of time to include the primary and secondary impacts. Major assumptions and simplifications for the drop analyses are listed in Section 5.0 of ST-557, Rev. 1.

The staff finds that the finite element model and the boundary conditions used are adequate to determine realistic results for the NCT load conditions.

### 2.9.1 Heat

The applicant considered an ambient temperature of 100°F in still air to calculate a maximum package bounding temperature of 182.7°F. This temperature occurs at a very small portion of the lid but is conservatively used for calculating the Maximum Normal Operating Pressure.

Table 3-2 and Figure 2-20 of the application tabulates and illustrates the pressures and temperatures in the package.

Tables 2-5 through 2-22 of the application tabulate the calculated stress intensities for the NCT and HAC conditions against the material allowable limits. The staff determined that the stress intensity values at critical components are within the allowable limits of the material and meets the regulatory requirements of 71.71(c)(1).

Section 2.6.1.2 of the application evaluates differential thermal expansion (DTE) of the package components under various loading conditions for possible interference resulting from a reduction in longitudinal gap sizes. Section 2.6.1.3 of the application evaluates the stresses in the package under the hot environment loading conditions. Those stresses are found to be well below their allowable values in Section 2.6.1.4.

The staff reviewed the structural performance of the package under the heat condition and concluded that the DTE and stress effects have properly been evaluated. A minimum safety factor of 1.36 occurs in the baseplate. Thus, the requirements of 10 CFR 71.71(c)(1) are satisfied.

2.9.2 Cold

Section 2.6.2 of the application evaluates the effects of cold environment on the package performance by considering an ambient temperature of -40°F combined with two cases, i.e., a maximum decay heat load and another with no decay heat load.

The maximum stresses in various components of the package under the cold environment loading conditions and their comparison with allowable values are presented in Table 2-6 of the application. Of all components, a minimum safety factor of 1.48 occurs in the baseplate. Thus, the staff agrees with the applicant's conclusion on the NCT cold condition and determines that the requirements of 10 CFR 71.71(c)(2) are satisfied.

2.9.3 Reduced External Pressure

The stresses in the 3-60 B package under reduced external pressure loading conditions are calculated by the applicant when performing the structural analyses of the cask under NCT. Stresses under reduced external pressure (46.2 psi) are compared with their allowable values. All components of the 3-60B package experience stresses well below their allowable values, with a minimum factor of safety of 1.45 in the baseplate.

Based on the review of the results in Table 2-7 of the application, the staff determined that the stress intensity values at critical components are within the allowable limits of the material and meets the regulatory requirements of 10 CFR 71.71(c)(3).

2.9.4 Increased External Pressure

The applicant evaluated the effect of an increased external pressure of 20 psi on the internal sealed cavity between the outer and inner shell of the package. The stresses in the package under increased external pressure loading conditions were calculated by the applicant when performing the structural analyses of the cask under NCT. Stresses under increased external pressure are compared with their allowable values. There is a minimum factor of safety of 1.59 in the baseplate.

Based on the review of the results in Table 2-8 of the application, the staff determined that the stress intensity values at critical components are within the allowable limits of the material and meets the regulatory requirements of 10 CFR 71.71(c)(4).

2.9.5 Vibration

The applicant demonstrated that the effects of vibration incident to transport are not significant for the package. The package impact limiter attachments, trunnion, shell, and cask lid closure bolts are analyzed for fatigue under normal transportation vibration load conditions in accordance with ANSI N14.23, 1998. Assuming that the package on the conveyance has a natural frequency of 2 Hz, the cask will be subject to a load cycle of $1.6 \times 10^8$ cycles over the package lifetime. Therefore, it was determined that a 64% reduction in material ultimate tensile strength takes place over the life of the package under cyclic conditions. Stresses for the cask closure bolts and impact limiter attachment bolts were calculated and checked against allowable limits for fatigue conditions. The staff reviewed the calculations, and determined that the stress intensity values are within the allowable limits of the materials and meet the requirements of 10 CFR 71.71(c)(5).

The package impact limiter attachments, trunnion, shell, and cask lid closure bolts were also analyzed for a shock loading coefficient of 1.5 in three orthogonal directions for transportation conditions, in accordance with ANSI N14.23, 1998. The trunnions were analyzed for the 10W longitudinal, 5W lateral, and 2W vertical loading. The 1.5 load factor is smaller than the load factors for shock loading in all directions. Therefore, the analyses bound the shock loading evaluation of the trunnions and the shell. Each impact limiter attachment assembly (subject to a shock load of 787.5 lbs force due to shock loading) has been shown to withstand the capacity of 60,000 lbs under HAC drop conditions. Therefore, they are capable of withstanding the shock loading on the package during transportation. The package lid has been shown to withstand a 61.8g loading on the lid in the longitudinal direction. The 1.5W loading is much smaller and will be bounded by the 61.8g loading.

The staff concluded that the shock loading coefficient of 2.9 may be more appropriate for these conditions by applying the approach provided in Section 4.0, and Figure 1, of ANSI N14.23, 1998. However, with the approximate amplification of 2 (due to a factor of 2.9 versus 1.5,) the package still remains within the defined allowable conditions. The staff determined that the trunnion, shell, impact limiter attachments, and closure bolts are adequately evaluated for the shock loading conditions, thus meeting the requirements of 10 CFR 71.71(c)(5).

2.9.6 Water Spray

Section 2.6.6 of the application notes that due to the material of construction, i.e., stainless steel, the water spray test will not significantly affect the package, and the staff agrees with the applicant’s conclusion that the requirements regarding the water spray test of 10 CFR 71.71(c)(6) are satisfied.

2.9.7 4 Foot Free Drop

The applicant performed dynamic analyses of the package in the end, side, and center of gravity (CG) over corner orientations, as well as two shallow angle orientations. The application summarizes the results of the package dynamic analyses of the NCT free drop, i.e., impact limiter reaction, average acceleration, approximate pulse duration and maximum crush of the impact limiters.

The stress intensity levels for components at the worst locations were tabulated in Tables 2-10 and 2-11 of the application. The staff verified that a minimum safety factor of 1.18 was reached at the inner shell for the stress category of primary membrane for cold condition NCT End Drop.

The stress intensity levels for the components at the worst locations were tabulated in Tables 2-12 and 2-13. The staff verified that a minimum safety factor of 1.11 was reached at the bolting ring skirt for the stress category of primary longitudinal (membrane) plus primary bending for hot condition NCT Side Drop.

The stress intensity levels for the components at the worst locations were tabulated in Tables 2-14 and 2-15. The staff verified that a minimum safety factor of 1.08 was reached at the bolting ring shell extension for the stress category of primary longitudinal (membrane) plus primary bending for cold condition NCT Corner Drop.

The staff reviewed these results and agrees with the applicant's conclusion that the package is capable of maintaining its structural integrity, and meets the requirements of 10 CFR 71.71(c)(7).

2.9.8 Corner Drop

The 3-60B package is not a fiberboard, wood, or fissile material package. Therefore, the corner drop test in 10 CFR 71.71(c)(8) does not apply.

2.9.9 Compression

The 3-60B package weighs more than 11,000 pounds. Thus, the requirements of 10 CFR 71.71(c)(9) are not applicable.

2.9.10 Penetration

The applicant demonstrated compliance by calculating the penetration depth of a 13 pound 1 ¼' diameter rod dropped from a height of 40" and reasonably concluded that the thicknesses of the outer shell, the lid, and the outer baseplate are greater than the depth required for penetration. In addition, no credit has been taken for the lead shielding and the inner shell.

Thus, the staff agrees with the applicant's conclusion that the package is not damaged by the NCT penetration and satisfies the requirements of 10 CFR 71.71(c)(10).

2.10 Hypothetical Accident Conditions

The applicant describes the details of their finite element model in Energy*Solutions* report ST-557, Rev. 1, and the HAC conditions use the same 180° ANSYS finite element model than for the NCT drop conditions. An explicit dynamic finite element code, ANSYS/LS-DYNA, is used to predict the deceleration levels for the drop cases. The deceleration levels are then taken to perform quasi-static analyses using the finite element code, ANSYS. The rigid body motion is prevented in the model by restraining it at the locations where such restraints had insignificant effect on the overall behavior of the model. The major assumptions and simplifications for the drop analyses were listed in Section 5.0 of ST-557, Rev. 1. The cask model was made using three-dimensional 8-node structural solid elements (ANSYS SOLID185) to represent the major components of the cask, cask body, lid, and bolts. The shell components of the cask – the inner and outer shells, and the base-plates have been represented in the finite element model by SOLSH190 elements.

The finite element transient analyses are performed for sufficiently large durations so that the primary, as well as secondary impacts, if any, are included. The time-history data of the reaction forces between the package and the rigid contact surface are obtained for each load case. The time-history of the results are examined for various quantities such as the kinetic energy, internal energy, total energy, hourglass energy, and the external work. The time history data of the maximum impact limiter crush are also obtained for each load case. The impact-limiter attachment load time-histories are also obtained for each drop orientation.

The staff finds that the finite element model and the boundary conditions used are adequate to determine realistic results for the HAC load conditions.

2.10.1 9-Meter Free Drop

Section 2.7.1 of the application presents a structural evaluation of the 3-60B package by analytical methods for the HAC 9-meter (30-foot) free drop tests. Analyses of the 3-60B package have been performed in the three customary drop orientations, i.e., end drop, side drop, corner drop, as well as two other orientations, i.e., shallow angles of 7.5º and 15º drops with a slap-down effect that is deemed to result in a larger reaction than the three customary orientations.

The major components of the package, the package body, the lid and the bolts, are represented by ANSYS SOLID 185; the poured lead is not bonded to the steel and the interface between the poured lead and the steel is modeled by contact-target pairs, as is also the case for the interface between the two plates that constitute the lead.

To envelop the entire spectrum of the temperature range, i.e., from -20°F to 100°F, the dynamic analyses of the package are performed for two initial conditions – the cold condition (Ambient temperature -20°F) and the hot condition (100°F). To be conservative, the larger of the two results are used for the detailed analyses of the package. The impact limiter reaction forces are obtained from the applicant's Drop Analysis Report, ST-557, Rev. 1. The impact-limiter reaction forces for all HAC drop orientations and hot (100°F) and cold (-40°F) temperatures are tabulated in Table 2-16 of the application and a factor of 1.1 is used to increase the reaction in the end drop, side drop, and corner drop HAC analyses.

The stress intensity levels for components at the worst locations are tabulated in Tables 2-17 (Hot) and 2-18 (Cold) of the application for the end drop test. The staff verified that a minimum safety factor of 1.14 was reached at the bolting ring shell extension for the stress category of primary membrane and at the lid for the stress category of primary membrane for cold condition HAC End Drop.

The stress intensity levels for components at the worst locations are tabulated in Tables 2-19 (Hot) and 2-20 (Cold) of the application for the side drop. The staff verified that a minimum safety factor of 1.09 is reached at the outer shell for the stress category of primary membrane for cold condition HAC Side Drop.

The stress intensity levels for components at the worst locations for the corner drop are tabulated in Tables 2-21 (Hot) and 2-22 (Cold) of the application and the staff verified that a minimum safety factor of 1.08 is reached at the bolting ring shell extension for the stress category of primary longitudinal (membrane) plus primary bending for cold condition HAC Corner Drop.

The package was also analyzed for two oblique drop cases (also referred to as slap down or shallow angle drop conditions). The first case occurred at an angle of 7.5° between the unyielding surface and the horizontal orientation of the cask. The second case was a 15° oblique angle. The two drop angles were considered for hot and cold test conditions. The applicant used the ANSYS/LS-DYNA explicit finite element code to determine the maximum impact limiter resultant forces for the oblique drops. Table 2-23 of the application lists the impact limiter reaction forces for the slap down HAC drop conditions. The applicant only considers the secondary (also referred to as tail) impact due to the l/r aspect ratio. Staff independently verified the aspect ratio, and determined that this approach is acceptable. Staff reviewed Sandia Report SAND90-2187, titled “An Analysis of Parameters Affecting Slapdown of Transportation Packages,” in making such a determination. Since the applicant is only considering the secondary impact for this drop case, the nature of this drop condition is related to the side drop condition. The amplification due to the secondary impact oblique drop is 1.06 times greater than that of the side drop condition. The side drop test results indicate that the minimum safety factor was 1.09 (which is greater than the 1.06 oblique amplification), the minimum safety factor required is provided.

The package was analyzed for lead slumping during the HAC conditions. During the HAC drop conditions, the lead shielding is subject to the highest accelerations during a cold bottom down end drop scenario. The maximum relative deformation of the lead shielding was calculated as 0.3172 inch at the bolting ring-lead interface (with elastic recovery neglected).

The impact-limiter attachment, shell, and weld were evaluated against the maximum attachment force taken from Table 2-23 of the application. The staff reviewed the hand calculations performed in ST-549, Rev. 1, and concluded that all evaluated components meet the required limits.

The shell buckling evaluation of the package was performed in Energy*Solutions* report, ST-600, Rev. 0. The ASME Boiler and Pressure Vessel Code Case N-284 was used to evaluate the shell buckling. The buckling requirement of Regulatory Guide 7.6 (“buckling should not occur as the result of any normal or accident condition loading”) is satisfied by demonstrating that the package meets the requirements of this code case. Consistent with Regulatory Guide 7.6 philosophy, the NCT is considered to be the ASME Service Level A condition, and HAC is considered to be Service Level D condition. The most vulnerable component of the package for buckling is its inner shell since it is the thinnest component and is subjected to both axial and hoop compressions. The axial compressive stress in this shell arises from the end and corner drops and the hoop compression occurs due to shrinkage of the lead over the inner shell in the cold environment. In order to obtain the maximum components of these stresses, all the loading combinations are examined.

The package drain port assembly was evaluated against the maximum impact limiter impact-limiter reaction force taken from Table 2-16 of the application. The staff reviewed the hand calculations performed in ST-549, Rev. 1, and performed independent hand calculations to confirm and conclude that the drain port assembly weld attachment to the outer shell met the required weld limit.

After review of the bolting ring enclosure under HAC drop conditions, the staff noticed large stress intensities in the cask body under side and corner drop conditions which may result in permanent deformation in these regions of high stress. The deformations will bring the bolting skirt into contact with the lid, and a part of the impact limiter reaction will be transferred to the lid bolts. Therefore, the staff required the applicant to demonstrate that the lid bolts remain within the elastic material limits under the side and corner HAC drop cases. The applicant provided an inelastic analysis of the bolting ring skirt under HAC drop loadings for the corner and side drops in Energy*Solutions* report ST-609, Rev. 1. Staff performed an independent verification and determined the minimum safety factor is achieved during the test conditions, and the closure bolts will resist the transfer of loading and remain within linear elastic material limits.

The 30-foot free drop tests, in aggregate, as demonstrated by analytical methods, satisfy the requirements of 10 CFR 71.73(c)(1).

2.10.2 Crush

The application notes that the crush test does not apply because the package weighs more than 1,100 pounds. Therefore, the requirements of 10 CFR 71.73(c)(2) are not applicable.

2.10.3 Puncture

The applicant determined through calculations that the 1 ¼" thick outer shell of the package will not be pierced by the puncture drop test, a 6" diameter mild steel rod from a height of 40", as specified in 10CFR 71.73 (c).

The applicant substantiated the above finding by performing additional finite element analyses for evaluating the puncture drop on the cask lid, package wall and ends. The maximum stress intensity in the package and in the lid and bolts under hot and cold conditions was found to be 41,568 psi and 41,157 psi respectively, i.e., well below the ultimate tensile strength of ASTM A 240 Type 304 L.(70,000 psi). Thus, the package can withstand the drop on the puncture bar without rupture.

This demonstrates the adequate structural integrity of the package to meet the 10 CFR 71.73(c)(3) requirements.

2.10.4 Thermal

Section 3.0 of this Safety Evaluation Report describes the thermal performance of the package. Differential thermal expansion is included in the stress evaluation of the package. Table 2-23 of the application presents the maximum stresses in the various components of the package under HAC fire test conditions and compares them with their allowable values. A minimum safety factor of 1.02 occurs in the bolting ring skirt extension. However, this stress is secondary in nature and does not affect the package.

This satisfies the requirements of 10 CFR 71.73 (c)(4).

2.10.5 Immersion - Fissile Material

The applicant stated that the package does not contain fissile material. Therefore, 10 CFR 71.73(c)(5) is not applicable.

2.10.6 Immersion - All Packages

The Model No. 3-60B package is a Type B package required to meet the water immersion test. The applicant did evaluate the package and the sealed inner cavity for an increased external pressure of 25 psig, i.e., greater than the 21.7 psig equivalent pressure due to immersion under 50 feet of water. The conclusion was that the 21.7 psig pressure was insignificant to the structural integrity of the package. Therefore, the structural performance of the package satisfies the water immersion test requirements of 10 CFR 71.73(c)(6).

2.10.7 Deep Water Immersion Test

The test is not applicable. The package does not transport irradiated fuel.

2.11 Evaluation Findings

The application demonstrates that the Model No. 3-60B package can withstand HAC test conditions. During the drop tests, the impact limiters may undergo some damage, as indicated below:

- During the HAC drop tests, the impact limiter skin may buckle and/or rupture in the vicinity of impact. The rupture may expose a portion of the polyurethane foam that is contained inside the steel skin.

- During the side and corner drop tests, the skirt extension of the bolting-ring may deform slightly near the point of impact. This component is away from the containment boundary of the package and a slight local deformation will not have any effect on the package performance prior to the fire tests. Inelastic analyses of the bolting ring skirt under those loading conditions under which it experiences high stresses (side and corner drop conditions) were performed in Energy*Solutions* document ST-609, Rev. 1. The skirt, under these loading conditions, accumulates less than 2% plastic strain and the bolts in the vicinity of the plastic deformation will experience stresses that are within the allowable values.

- During the puncture drop test on the sidewall of the package, the fire shield, which is designed to have a separation from the outer shell, may come in contact with the outer shell due to a deformation of the helically wound wire. The loss of separation will only be in the close vicinity of the puncture bar end. This will decrease the thermal resistance in that local area while increasing slightly the temperatures from those calculated for the intact package. In the area of the outer shell surface, the temperatures are well within the acceptable value. No unacceptable stress increase is expected because of this slight increase in the local temperatures.

- During the puncture drop test on the impact limiters, the outer steel skin will deform significantly due to a large compression of the polyurethane foam at the point of impact.

This may expose a portion of the foam, but the seating surface of the impact limiters, which includes the impact limiter attachments, remains intact as shown in the analysis. Therefore, during the HAC fire test, only this component of the impact limiters is assumed to provide thermal insulation (see Section 3.1.1 of the application),

- The puncture drop test will not cause a direct impact with any of the port closure plates.

Based on review of the statements and representations in the application, the staff concludes that the structural design has been adequately described and evaluated and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

## 3.0 THERMAL EVALUATION

The objective of the thermal review is to verify that the thermal performance meets the requirements of 10 CFR Part 71, including performance under NCT and HAC.

### 3.1 Thermal Design

Two components contribute to the thermal protection of the Model No. 3-60B package, i.e., the fire shield and the impact limiter. The fire shield is made of 12-gauge stainless steel sheet metal. To provide an air gap between the package outer shell and the fire shield, wires with a diameter of 5/32" are helically wrapped around the outer shell. The fire shield is also welded at the two ends of the package body. During an HAC fire, the air gap provides a thermal barrier which impedes heat transfer from the fire shield to the package.

The package's impact limiters are the sheet metal enclosures, filled with the polyurethane foam, serving as an insulation barrier to heat flow. The impact limiters provide the package thermal insulation during NCT. In addition, during the HAC fire event, the assumption was made that the sheet metal enclosing the polyurethane foam would be damaged during the HAC drop and puncture tests, thus reducing the effectiveness of the foam to provide full thermal insulation. The staff accepted this assumption because the damage to the sheet metal will increase the heat transfer into the package during the HAC fire, and provide a more conservative thermal evaluation.

The maximum decay heat for this package is 500 watts.

### 3.2 Material Properties and Component Specifications

The material properties of the cask components are provided in Tables 3-5 through 3-7 of the application. Those properties were obtained from standard reference handbooks.

### 3.3 Thermal Evaluation for Normal Conditions of Transport

The applicant analyzed the thermal performance of the package design under NCT and provided temperature-dependent material properties for all major components of the package as well as acceptable temperature ranges of operation.

The applicant constructed a $11.25^0$ symmetry ANSYS model of the packaging and analyzed it for the following loading conditions: Hot Environment ($100^0$ F ambient temperature, solar insolation, maximum internal heat load); Cold Environment ($-40^0$ F ambient temperature, no solar insolation and maximum internal heat load); Normal Hot ($100^0$ F, no solar insolation and maximum internal heat load); Normal Cold (-20º F, no solar insolation and maximum internal heat load).

Radiation and conduction heat transfer take place within the air gap between the ends of the package and the impact limiter plate. The heat transfer by radiation between the fire shield and the ambient air is modeled in the thermal evaluation. Heat transfer by natural convection is also accounted for within this model between the fire shield and ambient air. To take credit for convection, the heat transfer coefficient for natural convection is multiplied by the area applicable for this geometry and the temperature difference between the package surface temperature and the ambient temperature.

The applicant presented the predicted component temperatures of fire shield, outer shell, inner shell, lead, and seals in Table No. 3-1 of the application for NCT. Each component is below the corresponding maximum allowable temperature limit, as described in the application. The maximum temperature calculated for the fire shield under NCT is 177.7ºF, which falls below the maximum allowable temperature of 185°F, dictated by 10 CFR 71.43(g) in an exclusive use shipment. In addition, the applicant calculated the maximum package cavity temperature of 227.3ºF which both are below the allowable limit of 350ºF under NCT.

The applicant calculated a maximum pressure of 35.0 psig, as shown in Table No. 3-4 of the application, by adding the pressures generated from the radiolysis, the thermal expansion and the release of the water vapor for NCT.

The applicant determined the hydrogen generation rate, using the methodology developed by DOE for transuranic waste, with a number of conservative assumptions, such as the bounding G value for water, and the 100% absorption of decay heat by the contents. The staff reviewed both methodology and sample calculations, and agreed that the hydrogen generation can be limited to less than 5% by limiting the decay heat for contents that include water, in compliance with 10 CFR 71.43(d).

**Table 3-1: Component Temperatures under Normal Conditions of Transport**

| Component | Calculated Temperature | Maximum Allowable Temperature |
|---|---|---|
| Fire Shield | 177.7°F | 185°F |
| Outer Shell | 177.6°F | Set by Stress Conditions |
| Inner Shell | 177.8°F | Set by Stress Conditions |
| Lead | 178.9°F | 622°F |
| Seals | 178.6°F | 350°F |

The analysis of the NCT thermal conditions shows that there are no adverse effects and no reduction in packaging effectiveness for NCT.

3.4 Thermal Evaluation for Hypothetical Accident Conditions

The fire transient was run for 30 minutes (1,800 seconds) and the cool-down analysis of the model was performed with the body temperature resulting from the above transient to 14,000 seconds. From the analysis of the finite element model, a time-history data of the temperature in various components of the cask is obtained. During the fire test, heat is transferred from the fire source to the package by a combination of radiation and forced convection. Therefore, the total heat flow rate to the cask is a function of the resistance provided by the air gap and the equivalent resistance of the radiation heat transfer from the fire shield and the cask outer shell. The applicant incorporated these heat transfer phenomena into the thermal model by modeling the air mass resistance with the temperature-dependent conductivity and the radiation heat transfer.

The applicant presented the predicted component temperatures of fire shield, outer shell, inner shell, lead, and seals in Table No. 3-2 of the application for HAC. Each of the components is below the corresponding maximum allowable temperature limit. The maximum temperature calculated for the fire shield under HAC is 1331ºF. In addition, the applicant calculated the maximum cask cavity temperature of 329.3ºF and the maximum waste container temperature of 294ºF which both are below the allowable limit of 350ºF under HAC.

The applicant predicted a maximum pressure of 100 psig, as shown in Table No. 3–4, for HAC. These calculated pressures were used in the General Information, Structural Evaluation, Containment, and Acceptance Tests and Maintenance Program sections of the application.

**Table 3-2: Component Temperatures under Hypothetical Accident Conditions**

| Component | Calculated Temperature | Maximum Allowable Temperature |
|---|---|---|
| Fire Shield | 1331°F | N/A |
| Outer Shell | 353.5°F | 800°F |
| Inner Shell | 284.1°F | 800°F |
| Lead | 301.6°F | 622°F |
| Seals | 295.7°F | 350°F |

3.5 Evaluation Findings

The staff has reviewed the package description, model evaluation, the material properties, and component specifications used in the thermal evaluation and has reasonable assurance that the information provides sufficient basis for evaluation of the package against the thermal requirements of 10 CFR Part 71.

The staff has reviewed the methods used in the thermal evaluation and has run the applicant's ANSYS files to verify the results given in the application. The staff has reasonable assurance that the models are described in sufficient detail to permit an independent review of the package thermal design. The application of the analysis methods, presented in the application, to this package design has been found to be adequate. The staff has reviewed the accessible surface temperatures of the package, as it will be prepared for shipment, and has reasonable assurance that the package material and component temperatures will not exceed the specified allowable limits of 10 CFR 71.71 and 71.73, and that the requirements of 10 CFR 71.43(g) for packages transported by exclusive-use vehicle have been satisfied.

Based on the staff's review of the thermal sections of the application, the staff finds reasonable assurance that the package meets the thermal standards of 10 CFR Part 71.

## 4.0 CONTAINMENT EVALUATION

The objective of this containment evaluation review is to verify that the package design satisfies the containment requirements of 10 CFR Part 71 under NCT and HAC.

4.1 Description of Containment System

The applicant defines the containment boundary as the inner steel shell of the packaging body together with its closure features, i.e., the lower surface of the cask lid, the primary lid bolts, the inner O-rings on the lid, and the vent and drain port plugs. The drain port, located at the bottom corner of the package, is primarily used to drain water from the cavity. The vent port, located in the closure lid, is primarily used when draining the cavity. The elastomer O-rings on the lid, and the vent and drain port plugs that have been evaluated, are butyl rubber, ethylene propylene rubber, and silicone rubber. There are no materials used as neutron absorbers or moderators in the package.

The staff reviewed the containment design features and verified that the application defines and describes the exact containment boundary, including containment vessel, welds, seals, bolts, and lid, as well as the vent and drain boundary penetrations and their method of closure. The staff verified that all components of the containment system are shown in the Drawing No.C-002-165024-001 (sheets 1-5), in accordance with NUREG/CR-5502, "Engineering Drawings for 10 CFR 71 Package Approvals." The staff determined that the package design description is in compliance with 10 CFR 71.33 and 71.43.

All the containment boundary welds are non-destructively examined, using radiographic examination, for the containment welds between the bolting ring and the inner shell, the inner shell and the cavity bottom plate, as well as any seam weld on the inner shell of the package. The staff confirmed that the proposed weld inspections are marked on Drawing No.C-002-165024-001, sheet 2, and are examined by the ASME B&PV code.

The applicant performed a thermal analysis with a maximum heat load of 500 watts and predicted the NCT and HAC temperature profiles. The staff verified that the maximum temperatures of the O-ring seals of 178.6$^{o}$F and 295.7$^{o}$F, for NCT and HAC respectively, are below the allowable temperature limit of 450$^{o}$F and remain within the safety margins under NCT and HAC, without relying on any mechanical cooling system.

## 4.2 General Considerations

The applicant specifies that hydrogen and oxygen, produced by the radiolysis decomposition of a small amount of water remaining after draining the package cavity, and the hydrogen concentration must be limited to less than 5 % (by volume) in the package by limiting the maximum decay heat of contents that include water, to prevent the formation of a flammable mixture. The applicant derived the equation of the hydrogen generation rate as a function of the decay heat, the void space in the vessel cavity, and the weight fraction of water in the contents; the applicant then calculated the decay heat limit that will result in a 5 % hydrogen concentration at the end of a 60-day shipping period. The staff reviewed the equations derived for the hydrogen generation and the sample calculations for contents such as irradiated hardware, dewatered swarf, dewatered inorganic resin, and solidified liquid, and determined that the hydrogen generation analysis is acceptable and in accordance with the requirements of 10 CFR 71.43(d).

## 4.3 Containment under NCT

The Model No. 3-60B package is designed, fabricated, and leak tested to preclude the release of radioactive materials in excess of the limits prescribed in 10 CFR 71.51(a)(1).

### 4.3.1 Containment Design Criterion

The applicant calculated the maximum internal pressure of the package by assuming that the gas behaves as an ideal gas, and determined a maximum normal operating pressure (MNOP) of 35.0 psig and a minimum test pressure of 52.5 psig, as required by 10 CFR 71.85(b). The applicant will hold the test pressure for a minimum of 10 minutes prior to beginning any examination, and following the 10-minute hold time, will examine the package body, the lid, and the lid/body closure for leakage. The staff verified that the MNOP of 35.0 psig and the maximum cavity temperature of 227.3°F under NCT are consistent with the maximum pressure in Table 3-4 and the maximum cavity temperature in Table 3-3 of the application.

### 4.3.2 Demonstration of Compliance with Containment Design Criterion

Both powdered solids and irradiated hardware are considered representative of the various types and forms of contents for the leak rate analyses under NCT.

Powdered Solids

The applicant used the methodology in NUREG/CR-6487, determined a maximum permissible volumetric leakage rate of $9.26 \times 10^{-6}$ $cm^3$/sec , derived the standard air leakage rate of $4.28 \times 10^{-6}$ ref-$cm^3$/sec and the corresponding maximum diameter of the hole, $4.07 \times 10^{-4}$ cm for NCT based on the equations (B.3) and (B.4) of ANSI N14.5.

Irradiated Hardware

The applicant assumed that the worst case for irradiated hardware is control rod blades having the same type and level of surface contamination as spent fuel, and that the potentially releasable contents from the control rod blades is entirely from this surface contamination. Under this worst scenario, the applicant derived the standard air leakage rate of $1.54 \times 10^{-6}$ ref-$cm^3$/sec and the corresponding maximum diameter of the hole, $3.08 \times 10^{-4}$ cm for NCT, based on the equations (B.3) and (B.4) of ANSI N14.5.

The staff reviewed the temperatures and pressures in the thermal chapter of the application, verified Reference 4-2 for the geometry and the weight of the irradiated hardware (control rod blade) used in the calculation, and identified the assumptions and equations in NUREG/CR-6487 and ANSI N14.5 for the calculations of maximum permissible leak rates under NCT. The staff determined that the leakage rate calculations of powdered solids and irradiated hardware are in compliance with 10 CFR 71.51(a)(1).

## 4.4 Containment under HAC

The 3-60B package is designed, fabricated, and leak tested to preclude the release of the radioactive materials in excess of the limits prescribed in 10 CFR 71.51(a)(2).

### 4.4.1 Containment Design Criterion

Powdered Solids: The methodology and calculations of the permissible volumetric leak rates under HAC are similar to those under NCT. The applicant derived the standard air leakage rate of 0.009 ref-$cm^3$/sec and the corresponding maximum diameter of the hole, $2.96 \times 10^{-3}$ cm for HAC.

Irradiated Hardware: The methodology and calculations of the permissible volumetric leak rates under HAC are similar to those under NCT. The applicant derived the standard air leakage rate of $4.90 \times 10^{-4}$ ref-$cm^3$/sec and the corresponding maximum diameter of the hole, $1.41 \times 10^{-3}$ cm for HAC, using the equations (B.3) and (B.4) of ANSI N14.5.

The applicant presented the leak rates in Section No. 4.4 of the application, and concluded that the leakage rate of $1.54 \times 10^{-6}$ ref-$cm^3$/sec, for irradiated hardware under NCT, is the most restrictive leak rate for the Model No. 3-60B package.

### 4.4.2 Demonstration of Compliance with Containment Design Criterion

The staff reviewed the methodology and calculations for both powdered solids and irradiated hardware under NCT and HAC. The staff determined that the leak rate of $1.54 \times 10^{-6}$ ref-$cm^3$/sec is the bounding leak rate and constitutes the acceptance criterion for the package maintenance, fabrication, and periodic tests, in compliance with the 10 CFR 71.35, 71.51(a)(1) and 71.51(a)(2).

4.5 Leakage Rate Tests for Type B Package

Equivalent Reference Leakage Rates for helium and halogen gases (R-12 and R-134a)

The applicant assumed in Section Nos. 4.5.1, 4.5.2, and 4.5.3, of the application that the package void is pressurized from the evacuated 20-inch Hg vacuum to 42 psig for the halogen test gases (R-12 and R-134) and 1 psig for helium, and calculated the equivalent leakage rates of the halogen gases (R-12 and R-134a) and helium based on the standard leakage rate of $1.54 \times 10^{-6}$ ref-$cm^3$/sec and the corresponding maximum hole diameter of $3.08 \times 10^{-4}$ cm. The applicant presented the allowable test leakage rates ($cm^3$/s) of R-12, R-134a, and helium in Figure Nos. 4.5, 4.9, and 4.13, respectively, and the corresponding allowable test leakage sensitivities of R-12, R-134a, and helium in Figure Nos. 4.7, 4.1, and 4.14 of the application.

The staff reviewed the data used for calculations and performed confirmatory analyses for all three test gases by repeating the ANSI N14.5 calculations. The staff verified that the equivalent reference leakage rates of helium, and halogen (R-12 and R-134a) test gases are calculated in accordance with ANSI N14.5 and comply with 10 CFR 71.35, 71.51(a)(1) and 71.51(a)(2).

Pre-shipment Leakage Tests

The pre-shipment leak test is performed on the closure lid, vent port, and drain port using the gas pressure drop method with dry air or nitrogen. The minimum hold time for the gas pressure drop test for each of three components was calculated using the methodology and the equation B.14 from ANSI N14.5. The acceptance criteria for the pre-shipment leak test is a leakage rate less than $1 \times 10^{-3}$ ref-$cm^3$/sec per ANSI N14.5. The pre-shipment leak tests of the closure lid, vent port, and drain port are conducted by charging the annulus between the O-rings with air or nitrogen and holding the pressure for the determined hold time of 15 minutes. The staff verified the proposed test conditions and the related equations in ANSI N14.5, and determined that a leak test period of 15 minutes is acceptable and conservative for the pre-shipment leak test on the closure lid, drain port, and vent port.

4.6 Evaluation Findings

Based on the review of the statements and representations in the application, the staff concludes that the Model No. 3-60B package containment design has been adequately described and evaluated and that the package design meets the containment requirements of 10 CFR Part 71.

## 5.0 SHIELDING EVALUATION

The objective of the shielding evaluation is to verify that the package design provides the necessary shielding for the contents to be shipped and that the shielding integrity and dose rate limits meet the requirements of 10 CFR Part 71, under NCT and HAC.

5.1 Shielding Design Features

The shielding features of the Model No. 3-60B package design include the following: (i) an outer 1 ¼ -inch thick steel stainless shell surrounding 6 inches of lead and an inner containment shell wall of ¾- inch thick stainless steel for the packaging sidewall, (ii) an outer 3-inch thick stainless steel shell, a 5-inch lead shield layer and a ¾ -inch inner containment layer for the packaging bottom, and (iii) a 10.5-inch thick lid consisting of several circular stainless steel plates.

5.2 Source Specification

The applicant analyzes two bounding configurations, i.e., the maximum authorized contents of irradiated hardware in a steel liner and the maximum authorized contents of dewatered dispersible solids e.g., swarf, in a polyethylene high integrity liner to calculate the maximum radiation levels during NCT and HAC. In both cases, the contents are assumed to be uniformly distributed throughout the liner and conservatively modeled as a Co-60 gamma source at 1110 TBq or 30,000 Ci.

5.3 Configuration of Source and Shielding

The applicant uses the SAS4 module of SCALE to calculate estimated dose rates and the BONAMI and NITAWL subroutines to process the 27n-18g coupled cross-section library. This library contains neutron data taken from the 27-group ENDF/B-IV library and gamma-ray data from the standard SCALE gamma library. Gamma data in this library is lacking for many nuclides; however none of these nuclides appear in the shielding model. Both the codes and libraries are appropriate in this application.

Both point and surface detectors (tallies) are used to determine the expected dose rate, with the largest tally being utilized in locations where the detectors coincide. The applicant states that a radial distance of 322 cm corresponds to 2 m from the edge of the exclusive use conveyance and presents the location of most surface point detectors in Figure Nos. 5.1 through 5.4 of the application.

5.4 Normal Conditions of Transport (NCT)

Both irradiated hardware (stainless steel reactor control blades) and swarf (irradiated metal cutting debris) are modeled under NCT conditions and are assumed to be uniformly distributed over the liner interior cavity. Dewatered swarf contains equal volumes of swarf and water (assuming a porosity of 50%) and the shielding effect of the water is conservatively ignored for swarf transportation.

SCALE's default locations for surface detectors are used for the radial and axial surface detectors with two exceptions: one detector is set to the outer radial surface of the impact limiter and another detector is set at 6 m from the outer surface. The axial locations of interest are at the package surface, at 2 m from the surface and at the expected occupied area of the tractor while in transit, i.e., at 6 m from the outer surface. The maximum dose rates under NCT are presented in Table No. 5-1 below.

Table No. 5-1
Maximum Dose Rates (mrem/hr)

| | Package Surface | 2 m from Surface | Occupied Space 6 m from Top or Bottom of Package |
|---|---|---|---|
| Top | 46.5 (swarf) | 3.8 (swarf) | 0.6 (swarf) |
| Bottom | 13.0 (swarf) | 1.0 (swarf) | 0.8 (swarf) |
| Side | 73.6 (hardware) | 7.7 (swarf) | N/A |

The highest dose rate, i.e., 73.6 mrem/hr at the side of the package, remains below the allowable limit of 200 mrem/hr.

5.5 Hypothetical Accident Conditions (HAC)

Under HAC, some changes are incorporated to the models, e.g., the impact limiters are removed for the axial analyses to conservatively determine the 1 m dose rate after a drop and lead slumping creates a 0.81 cm void in the lead shield at the top (lid side) of the package. The forces exerted are insufficient to change the geometry of the irradiated hardware; however swarf is assumed to compress at the bottom end of the package as a result of the drop. This effect was taken into account by modeling the fuel as water, to account for the interstitial liquid forced out by the impact. Due to symmetry limitations with SAS4, the radiation sources under HAC are divided into two 20 cm tall cylinders at the top and bottom of the cask. The source intensity is doubled to compensate for the source material being divided. The chosen density of 6 g/cm$^3$ is conservative compared to expected swarf compression. The applicant compressed the source volume beyond that of normal steel, intensifying the source, while reducing the assumed density to conservatively under predict the source material self-shielding. Point detectors are placed 1m away from the cask outer surface, both radially and axially, with 5 detectors bunched at the axial level of the void created by the lead slump.

The maximum dose rates under HAC are shown in Table No. 5-2 below.

Table No. 5-2

Maximum Dose Rates (mrem/hr)

| | Package Surface | 1 m from Surface | Occupied Space 6 m from Top or Bottom of Package |
|---|---|---|---|
| Top | N/A | 295 (swarf) | N/A |
| Bottom | N/A | 77.7 (swarf) | N/A |
| Side | N/A | 634 (swarf) | N/A |

5.6 Evaluation findings

The staff reviewed the description of the shielding components of the packaging design and contents and the applicant's calculations methods and results in the two bounding cases, including the SCALE input and output files for the Model No. 3-60B package, as provided in the application.

The staff conducted its own shielding analyses which confirmed that, given the materials and thickness of the lid, bottom and sides and the source geometry, the location of highest radiation dose is through the sides of the cask and the dose rate remains below allowable limits set forth in 10 CFR Part 71. The location of the detectors in the staff's evaluation was at the axial midpoint of the cask, and the appropriate distance from the cask body surface.

In both cases, the external doses rates for the Model No. 3-60B package at 1 m from the surface and 2 m from the vehicle comply with the limits specified in 10 CFR 71.47 and 71.51.

## 6.0 CRITICALITY EVALUATION

Compliance with 10 CFR criticality requirements is not applicable for this package since contents exceeding the fissile mass limits set forth in 10 CFR 71.15 are not authorized.

## 7.0 PACKAGE OPERATIONS

The objective of this review is to verify that the operating controls and procedures meet the requirements of 10 CFR Part 71 and are adequate to assure that the package will be operated in a manner consistent with its evaluation for approval.

### 7.1 Package Loading

Package loading operations may be performed either in a pool or in a dry loading area. Preparations for loading include visual and operational inspections of the empty packaging, detaching impact limiters from the packaging body, attaching lifting equipment to the trunnions, removing the vent port and lid bolts, inspecting the vent port, drain port, and lid O-rings and replacing them if necessary (in that case, leak testing is performed to a leakage rate less than $1.54 \times 10^{-6}$ ref-cm$^3$/sec, in accordance with ANSI N14.5.), and inspecting the accessible areas of the packaging cavity for damage, loose materials or moisture. When wet loading is used, the drain port plug must be removed and the package suspended until no water exits the drain port. Vacuum drying or inert gas backfilling is not required.

Prior to loading, a verification of the contents shall be performed for compliance with the conditions of the certificate and the maximum decay heat shall be determined to limit hydrogen generation for those contents loaded wet. The applicant must ensure that the contents, the secondary container, and the packaging are chemically compatible and will not react to produce flammable gases, in compliance with 10 CFR Part 71.

After loading, the lid bolts are installed hand-tight, the vent and drain port plugs are re-installed with their O-rings and seals, all remaining bolts are installed and torqued to 300 ft-lbs and the package exterior surfaces are decontaminated as necessary.

Preparation for transport includes pre-shipment leak tests of the cask lid, vent port and drain port plugs; moving the package to the conveyance area; attaching the impact limiters and the security seals as required, verifying the exterior surface temperature limits, performing the radiation and contamination surveys, package marking and labeling, and vehicle placarding. The applicant should verify that the exterior surface of the package does not exceed the temperature limits of 185ºF in an exclusive-use shipment, in compliance with 10 CFR 71.43(g) and 49 CFR 173.442.

### 7.2 Package Unloading

Package unloading operations include receipt of the package and removal of the contents. The package is inspected for any exterior damage, verification that the tamper-indicating seals are attached is done, radiation and contamination surveys are performed, impact limiters are removed from the package and the package is then placed in the work area in either the horizontal or vertical position. The lid is then removed and the contents unloaded.

### 7.3 Preparation of Package for Empty Transport

No special preparations or procedures are required for transporting an empty package other than the usual conditions that shall be confirmed before transport: the cavity is empty, the package is securely closed and the exterior of the package is confirmed to be unimpaired.

### 7.4 Evaluation Findings

The staff reviewed the Operating Procedures in Chapter No. 7 of the application to verify that the package will be operated in a manner that is consistent with its design evaluation. On the basis of its evaluation, the staff concludes that the combination of the engineered safety features and the operating procedures provide adequate measures and reasonable assurance for safe operation of the proposed design basis fuel in accordance with 10 CFR Part 71.

Further, the Certificate of Compliance is conditioned such that the package must be prepared for shipment and operated in accordance with the Operating Procedures specified in Chapter No. 7 of the application.

## 8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The objective of this evaluation is to verify that the acceptance tests for the packaging meet the regulatory requirements, and that the maintenance program is adequate to ensure packaging performance during its service life.

### 8.1 Acceptance Tests

Section 8.1 of the application specifies review, inspection, and testing of the package. The acceptance tests and inspections considered critical to the safe operation of the 3-60B package are included as conditions in the certificate.

Packaging dimensions, tolerances, general notes, materials of construction and assembly are examined according to the information specified in the packaging drawings. Specifications are provided for the structural and pressure tests, for leakage tests prior to the acceptance and operation of a newly fabricated package, for shielding tests to verify the integrity of the shielding and to assure that the packaging is free of significant voids in the poured shield annulus, as well as for component and material testing. Weld examination standards and acceptance requirements are specified, e.g., the containment boundary welds and the non-containment boundary welds identified on drawing of C-002-165024-001 must meet the acceptance requirements of ASME P&PV Code, Section III, Div. 1, Subsection ND. The applicant will inspect the containment boundary welds between the bolting ring and the inner shell, and between the inner shell and the package cavity bottom plate, and any seam welds on the inner shell by radiographic examination.

Structural, pressure, component, and materials tests are performed as indicated in Sections No. 8.1.3 and 8.1.5 of the application. Leakage tests shall be performed prior to the acceptance and operation of a newly fabricated package. The fabrication leakage test is performed on the whole containment boundary, e.g., inner shell, base plate, and the inner O-rings at lid, vent port and drain port. While the package cavity is at a minimum of 20” Hg vacuum, the cavity is pressurized to a minimum pressure of 42 psig with pure R-12 or pure R-134a as tracer gas, and 1 psig with pure helium as tracer gas. Table No. 8.1 of the application shows the periodic leak tests performed on the package.

### 8.2 Maintenance Tests

Section No. 8.2 of the application provides the routine and periodic inspection and maintenance program for the Model No. 3-60B package. This section specifies that (i) defective items are replaced or remedied, including testing, as appropriate and (ii) inspections are performed prior to each use of the package, e.g., O-rings are inspected for any cracks, tears, cuts, or discontinuities that may prevent the O-rings from sealing properly.

Table No. 8.2 of the application identifies the pre-shipment leak tests of the Model No. 3-60B package components by pressurizing the annulus between the O-rings of either the lid or the vent port, and by pressurizing the inlet to the drain line with dry air or nitrogen. For contents that meet the definition of low specific activity material or surface contaminated objects in 10 CFR 71.4, and also meet the exemption standard for low specific activity material and surface contaminated objects in 10 CFR 71.14(b)(3)(i), the pre-shipment leak-test is not required. The test pressure should be applied for at least 15 minutes for the lid, the vent port and the drain port, and the leakage test should be tested to less than the reference air leakage rate of 1.0 x $10^{-3}$ ref-$cm^3$/sec.

The applicant performs periodic leak tests on the package within the preceding 12 month period before the actual use of the package for shipment, and after each seal replacement. The periodic leak tests on the O-rings at the lid, vent port, and drain port are performed by evacuating the cask cavity to 20" Hg and then pressurizing to 42 psig for the halogen test gases (R-12 and R-134a) and 1 psig for helium. As noted in ANSI N14.5, the mass spectrometer is capable of detection of leak rate of $10^{-8}$ $cm^3$/sec, which is much lower than the required sensitivity for the helium leak test. Therefore, the staff agrees that the mass spectrometer used for helium detection is much more sensitive than a halogen detector, and the less sensitive halogen detectors require a higher backfill pressure so that the sensitivity requirement can be met. The applicant states that some of the volume of the cavity may be temporarily filled with a cavity filler material, during the periodic leak tests for both the closure lid and the vent port, to reduce the volume of tracer test gas required to conduct the tests. A sealed right circular metal canister will be used as the filler material to partially fill the cavity during the periodic leak test and the installation is described in the test instruction of Section No. 8.1.4. of the application. The applicant should verify that the cavity filler material (the canister) has the standoff appendages necessary to ensure the drain opening is not obstructed and is chemically compatible with the package liner and the test gases, in compliance with 10 CFR 71.43(d).

In addition, seals are inspected each time the package lid, vent port or drain port are removed and seals are replaced within a 12 month period before shipment.

8.3 Evaluation Findings

The staff reviewed the acceptance tests and maintenance programs for the Model No. 3-60B package. The staff found them acceptable. Based on the statements and representations in the application, the staff concludes that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71. Further, the Certificate of Compliance is conditioned to specify that each package must meet the Acceptance Tests and Maintenance Program of Chapter No. 8 of the application.

**CONDITIONS**

The following conditions are included in the Certificate of Compliance:

(a) The package shall be prepared for shipment and operated in accordance with

Chapter 7 of the application.

(b) The package must be tested and maintained in accordance with Chapter 8 of the application.

(c) Contents shall be packaged in secondary containers.

(d) Shoring must be placed between the secondary container and the packaging cavity to prevent movement during accident conditions of transport.

(e) Contents shall be placed such that the center of gravity of the package is at approximately the same location as the geometric center of the package – “approximately the same location” being defined as having a ±10% difference in distance of the inside cavity dimensions from the geometric center of the package in any direction.

(f) Materials that auto-ignite or change phase below 350º F, not including water, shall not be included into the contents.

(g) Flammable gas (hydrogen) concentration is limited to less than 5 % in volume. Inerting is not allowed to limit the concentration of flammable gases.

**CONCLUSION**

Based on the statements and representations contained in the application, and the conditions listed above, the staff concludes that the Model No. 3-60B package has been adequately described and evaluated and that the package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9231, Revision No. 0,
on August 26, 2010.